Effect of Blood Flow Restriction Training and Whole Body Vibration on Muscular, Functional and Psychological Performance in Athletes following Anterior Cruciate Ligament Reconstruction

SHORT SYNOPSIS

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I hereby declare that the Short Synopsis titled "Effect of Blood Flow Restriction Training and Whole Body Vibration on Muscular, Functional and Psychological performance in Athletes following Anterior Cruciate Ligament Reconstruction" being submitted in partial fulfillment of the requirement for the degree of Doctor of Philosophy in the Department of Physiotherapy under School of Allied Health Sciences of Manav Rachna International Institute of Research & Studies, Faridabad during the academic year 2024-2025. It is a bona fide record of original work carried out under the supervision of Dr. Irshad Ahmad and has not been submitted in full or part to any other university or institute for degree or diploma. Further, it is certified that Short Synopsis is plagiarism free and proof has been submitted.

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Abstract

Background/Introduction: Anterior Cruciate Ligament Reconstruction is the optimal decision for an athlete to return to sports after an ACL tear. It is a surgical intervention in which the torn ACL is grafted to improve the knee's functions. Neuromuscular deficits are common after ACL injury. Functional recovery of the knee is incomplete in an athlete with ACL reconstruction if the rehabilitation does not include neuromuscular training.

Aims: This study aims to examine the effect of Blood flow restriction training and whole-body vibration on muscular, functional, and psychological performance in athletes following ACL reconstruction. It will also distinguish this result from the whole-body vibration-only protocol and blood flow restriction training individually.

Methodology: This study will be a Randomized Control Trial. There will be two control groups and one experimental group. Subjects will be selected using inclusion/exclusion criteria. These subjects will then be randomly assigned to the three groups (n=96). Outcome measures will be Pain, Muscle performance (Muscle girth, Isometric Strength and Peak Torque), functional performance (Balance-Static and Dynamic, Proprioception and Tegner Lysholm Knee Score) and KOOS. The experimental group will perform blood flow restriction exercises on the whole body vibration platform. One control group will perform whole-body vibration only, and the other will perform blood flow restriction only.

***Keywords**: Anterior Cruciate Ligament (ACL) reconstruction, blood flow restriction (BFR), neuromuscular function, proprioception, whole body vibration (WBV)*

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1. Description of Broad Area

1.1 Definition, Functions of ACL and Epidemiology of ACL Injury

The knee joint is a complex, weight-bearing joint. The stability of the joint is controlled by muscles, meniscus, tendons and ligaments. Ligaments play a major role in stabilizing the joint during movements. ACL is amongst the six ligaments of the knee joints(Marieswaran et al., 2018). The Anterior Cruciate Ligament prevents hyperextension of the knee by primarily restricting the anterior translation of the tibia over the femur (Marieswaran et. al.,2018). ACL also restricts tibial internal rotation(Noyes & Barber-Westin, 2018).

The medial aspect of the lateral femoral condyle is the site of origin of ACL, and the insertion point is the tibial plateau in the middle of the medial and lateral inter-condyles. Collagen fibers and mechanoreceptors are present inside the ACL. These mechanoreceptors play a crucial role in the proprioception of the knee joint(Domnick et al., 2016).

The main stabilizer of the knee is the ACL, which contributes to 85% of stabilization. (Abulhasan & Grey, 2017) ACL is an intra-articular ligament and, thus, affects the kinematics of the knee joint. (Domnick et al., 2016) The genicular artery supplies ACL, consisting of two bundles: anteromedial and posterolateral. The shorter being anteromedial bundle slack in extension while the posterolateral slack in flexion. 20-30 degrees of knee flexion is ideal for knee evaluation, as in this range, ACL is in the least tension. (Abulhasan & Grey, 2017)

ACL injury is the most common injury to athletes. Studies reveal that 55% of athletes who undergo ACL reconstruction return to their sports (Walker et al., 2020). In the USA, annual incidents of ACL injuries are over 200,000(Cavanaugh & Powers, 2017).

1.2 Mechanism of Injury and Consequences Associated

ACL injury either occurs through contact or non-contact. The non-contact injury occurs without any physical contact to the knee. Also, non-contact ACL injury is most common. This happens with a sudden pivoting or decelerating knee joint on the weight-bearing limb. (Yu & Garrett, 2007). Impaired quality of life, pain, inability to continue sports, re-injury and development of osteoarthritis (Filbay & Grindem, 2019) are the complications faced by an athlete post-ACL injury.

1.3 Neuromuscular Alteration and Proprioception Deficit after ACL Injury

By the action of afferent signals and resisting efferent signals, the nervous system of the body performs muscle functions and controls the movements of the body. This is called the neuromuscular function of the body. (Lai et al., 2017) Quadriceps and hamstring strength gets hampered, voluntary control of quadriceps gets affected, torque and angular velocity decrease, and changes occur in the pathways of spinal reflex following ACL injury. (Tayfur et al., 2021)

Reduced proprioception is a functional impairment, along with mechanical instability, which is very common in a torn ACL knee joint. Proprioceptive fibers have been found in the remains of the ACL. These fibers have mechanoreceptors in them, which improve proprioception with proper rehabilitation. (Dhillon et al., 2011)

1.4 ACL Reconstruction

Mayo Robson repaired the first torn ACL in 1985.(Mahapatra et al., 2018). Surgical intervention to correct and repair torn ACL is ACL Reconstruction. Autologous grafting is the choice of reconstruction due to lesser complications. Two types of grafts are considered for the repair: Hamstring tendon of semitendinosus and gracilis muscle and bone-patellar-tendon-bone. (Domnick et al., 2016)

Bone blocks are extracted from patella and tibial tubercle with patellar tendon is used in bone-patellar-tendon-bone graft. The semitendinosus and gracilis are the distal tendon which are taken from the tibial insertion. Then, these are stitched with one another giving four strands.(Meyers et al., 2010)

Graft from patellar tendon suggests better knee stability but increased joint pain in the anterior aspect in long term after reconstruction(Freedman et al., 2003)(Xie et al., 2015)

The hamstrings tendon regenerates after 6 months of surgical intervention and may even continue till 12-24 months. This regeneration is slow and may even not be regenerated completely, sometimes. Thus, it effects strength of muscles.(Bregenhof et al., 2018)

1.5 Resistance Exercises of Knee following ACL Reconstruction

In In ACL reconstruction rehabilitation, high-intensity resistance exercises improved muscle leg extensor power. (Bieler et al., 2014). Athletes return to their earlier sports

and develop quadriceps strength after ACL reconstruction. With quadriceps strength, they are less prone to develop osteoarthritis. (Bieler et al., 2014)

Strength training is an essential part of ACL reconstruction rehabilitation as it improves muscle strength, power, and muscle volume. However, heavy load resistance training is in the later phase of rehabilitation to prevent injury. (Augustsson, 2013)

1.6 Effect of Whole-Body Vibration on Neuromuscular Function

The capability of whole-body vibration in enhancing force-generating capacity has led to it being a rehabilitative technique lately. Results also show that it is useful in the treatment of sarcopenia and osteoporosis. Whole body vibration is performing exercises on vibrating platforms. These vibrations are sinusoidal vibrations, which are mechanical. (Cardinale & Wakeling, 2005) Neuromuscular function boosts with the whole body vibration exercise in neurological patients and normal people. It improves physical performance in patients. Joint Proprioception and balance also improve with whole-body vibration exercises. (Lai et al., 2017)

Motor control enhances with increased alpha motor neuron excitability and integration of motor units by performing whole-body vibration exercises. (Chang et al., 2021)

Mechanoreceptors sense vibrations, stimulate them and improve proprioception and balance. This, in turn, improves motor control of the body. (van der Zee et al., 2020)

1.7 Blood Flow Restriction and its Effect on ACL Reconstruction

Blood flow restriction with low resistance and low-pressure vascular occlusion can generate the same strength results, which are attained by high-resistance training (Hankemeier, 2019). Blood flow restriction restricts arterial blood flow partially and venous blood flow completely. Hypertrophy could be a result of increased metabolic stress and vascular endothelial growth by the hypoxic environment in the muscle. Various other factors could produce hypertrophy in the muscle, such as growth factors, anticatabolic and anabolic reactions and type 2 muscle fiber recruitment (Álvarez et al., 2021a).

1.8 Blood Flow Restriction and Whole-Body Vibration effect on ACL Reconstructed Athletes

Athletes, after ACL reconstruction, commonly complain of pain, muscle weakness, muscle atrophy, poor balance and proprioception during functional/sports-related

activities. As no single intervention results in the adequate and satisfactory rehabilitation of the athletes, this affects the performance of the athletes both during training and playing on the field.

A combination of blood flow restriction training on a whole body vibration platform can be an encouraging treatment protocol for athletes after ACL reconstruction. This study proposes to use this combination on athletes after ACL reconstruction for complete rehabilitation, which will effectively bypass the complications of muscle weakness and poor balance in the long run.

2. Literature Review

2.1 Effect of Resistance Training in ACL Reconstruction Rehabilitation

(Bieler et al., 2014): A randomized control trial was done on 50 participants to compare high-intensity resistance training and low-intensity resistance training on the power of knee extensors after ACL reconstruction. The group with high-intensity was randomly selected with 24 participants, and the low-intensity group consisted of 26 participants. The study was conducted for 20 weeks. A significantly improved result was found in the high-intensity resistance training group with more power in knee extensors.

2.2 Effect of Whole-Body Vibration in ACL Reconstruction Rehabilitation

(Costantino et al., 2018): The author evaluated 38 female athletes in a randomized controlled study to evaluate peak torque and power post-ACL reconstruction. Two groups were divided randomly. The control group was given the conventional protocol, while the experimental group followed whole-body vibration along with the conventional group. Although both groups showed effective results, the whole-body vibration group gave more enhanced outcomes. Muscular strength improved in the experimental group.

(Fu et al., 2013): The author assessed 48 ACL reconstruction patients in two groups. They were assigned randomly to these two groups. The experimental group received whole-body vibration and conventional protocol, while the control group only received conventional rehabilitation in the first month postoperatively. The outcome measure for the study was neuromuscular control. The researcher concluded that the experimental group had significant results in postural control, shuttle run, muscle performance, and single-legged hop compared to the control group.

(Berschin et al., 2014): A randomized control trial was done by the researcher on athletes with ACL reconstruction. The study was conducted for 10 weeks to examine the whole-body vibration effect after ACL reconstruction rehabilitation. Protocol started on the second week of rehabilitation and continued till the eleventh week. The control group was given the conventional training program, and the experimental group performed exercises on the whole-body vibration platform. There were 20 subjects in each group. The outcome measures for the study were neuromuscular function and the time spent on rehabilitation. After the end of the study, the researcher found significant differences in the whole-body vibration group in terms of time spent in rehabilitation and strength and coordination.

(Torvinen et al., 2002): This study assessed the outcomes of whole-body vibration for 4 minutes in young participants. The outcome measures of the study were muscle performance in lower limbs and body balance. The study was done on sixteen subjects randomly. The results of whole-body vibration training were observed 10 minutes before, 2 minutes after and 60 minutes after the training. In the end, the author found that the muscle performance of lower limbs and the balance of the body were enhanced.

(Moezy et al., 2008): A randomized control trial was performed on twenty subjects with ACL reconstruction to evaluate knee proprioception and postural stability. One group performed conventional training, and the experimental group performed 12 whole-body vibration sessions. The outcome measures were analyzed using a Biodex dynamometer and dynamic postural stability indices. The results at the end of the study showed better proprioception and balance in the experimental group than in the control group.

(Maghbouli et al., 2021): This is a systematic study of patients after ACL reconstruction to distinguish vibration therapy from conventional treatment. It is a systematic review and a meta-analysis study. They reviewed muscle torque and postural control. They summarised 13 randomized control trials and found that in ACL reconstruction patients, vibration therapy improves postural stability and peak torque.

(Y, 2015): A review was done to assess the whole-body vibration effect on ACL reconstructed patients. They reviewed postural control and knee position sense. 3 randomized control trials with 99 ACL reconstructed patients were thoroughly assessed. The meta-analysis statistical results revealed that whole-body vibration therapy is an effective treatment option in ACL rehabilitation.

(Seixas et al., 2020): This systematic review indicated improved effects of whole-body vibration treatment on patients with ACL reconstruction in terms of knee function, EMG activity, balance and strength. They studied 10 randomized control trials. They found that whole-body vibration training improves knee function, EMG activity, balance and strength in patients with ACL reconstruction.

2.3 Effect of Whole-Body Vibration in Older Population

(Rees et al., 2008): A study was conducted on thirty subjects with a mean age of 73.7 years in two groups to assess flexor and extensor muscle strength in all the lower limb joints. The subjects were allocated randomly to the two groups. One group followed exercise with whole body vibration while the other followed only exercises. The protocol followed for both groups consisted of sessions for 8 weeks. The author found a significant difference in ankle muscle strength in the whole-body vibration group, and knee and hip muscle strength was comparable to the exercise-only group.

(Jo et al., 2021): This study was performed in an older population to analyze muscle strength and physical performance using whole-body vibration. This is a randomized control trial where 20 participants were subjected to whole-body vibration with strengthening training, and 20 subjects were given a stretching and strengthening regimen. The treatment time for the two groups was 12 sessions. The researcher observed that there was a significant difference in the peak torque of the group with whole-body vibration with strengthening training.

(Machado et al., 2010): A randomized control trial was done on 26 randomly selected older women. It was done to assess whole body vibration effect on mobility, power, strength and muscle mass. 13 subjects were assigned equally in both the control group and the experimental group. The experimental group was the whole-body vibration group. After 10 weeks of intervention, the results showed improved strength, mobility and muscle mass.

(Wei et al., 2017): This study was conducted on 80 older adults who have muscle loss. All of them were distributed randomly in four uniform groups. The four groups were low-frequency long duration, medium-frequency medium time duration, and high-frequency short duration, and the fourth group was the control group with no exercise. The total duration of the study was 12 weeks, and then a follow-up was also done for

12 weeks. The results at the end of the study showed that whole-body vibration training with medium frequency and medium duration increased knee extension performance.

(Bogaerts et al., 2007): The researcher performed a randomized control trial to analyze the effect of whole-body vibration for one year on muscle strength and muscle mass in men with age above 60 years. They divided the participants randomly into three groups. One group was whole-body vibration with 31 subjects. This experimental group was compared to 30 individuals in a fitness group and 36 in a control group. Isometric and explosive muscle strength was assessed using an isokinetic dynamometer. The researcher concluded the whole-body vibration exercise improved isometric and explosive muscle strength and muscle mass.

2.4 Whole-Body Vibration Effect in other Musculoskeletal Conditions

(Zhang et al., 2021): This is a cross-sectional study on the effects of whole-body vibration at different angles and at various frequencies to assess muscle activation of lower limbs in knee osteoarthritic patients. Twenty-six subjects with knee osteoarthritis were included in the study. The parameters of assessment of whole-body vibration on muscle activation were 0, 30 and 60 of knee flexion with frequencies 0, 5, 10 and 20 Hz. The author found that while activation of muscle was enhanced in all the frequencies and at all the angles of the knee, the neuromuscular activation of muscles significantly improved at 60 degrees of knee flexion and 20 Hz of vibration frequency.

(Osawa & Oguma, 2013): This study was performed on thirty-three untrained subjects between 22 and 49 years of age, randomly divided into two groups. One group had whole-body vibration with resistance training, and the other had only resistance exercises to assess strength, power, endurance of muscles, and neuromuscular activities. Outcomes of the study showed a significant difference in lumbar extension, concentric knee extension and isometric knee extension strength, along with improved neuromuscular activity in whole-body vibration with the resistance training group.

(Yañez-Álvarez et al., 2020): A randomized control trial was performed on 50 patients with patellofemoral syndrome. The subjects were randomly distributed to the control and the experimental group. The experimental group used an exercise protocol with whole-body vibration, while the control group used the conventional exercise intervention only. The outcome measures were lower limb and knee function, range of motion and pain. Whole body vibration effect on the hip and knee strength and core

strength were analyzed. The researcher found that pain subsides, and the lower limb strengthens significantly in the whole-body vibration group.

(Sañudo et al., 2013): The author analyzed the whole-body vibration effect with exercise on patients with fibromyalgia. The assessment was to study the whole-body vibration effect on dynamic strength and balance. Forty-six females with fibromyalgia were divided randomly into three groups. The first group included 15 subjects performing exercise therapy two times a week and whole-body vibration three times a week. The second group consisted of 15 subjects who performed combined exercise therapy, and the third group, with 16 participants, was a control group with the usual care protocol. The outcome of the research demonstrated the significance of whole-body vibration with exercise training in improving balance and dynamic strength in patients with fibromyalgia.

2.5 Blood Flow Restriction on ACL Reconstruction

(Álvarez et al., 2021b): This is a systematic review of the randomized control trials. This study assessed the efficacy of blood flow restriction training on ACL rehabilitation and patients suffering from knee osteoarthritis. The data was extracted from 10 articles after the fulfilment of inclusion criteria. The outcome measures were to find the effects on the pain, function, cross-sectional area of quadriceps muscle and quality of life. They found improved pain in four studies and improved cross-sectional area of quadriceps in two studies.

(Ohta et al., 2003): A randomized control trial was performed on 44 participants with ACL reconstruction to examine the moderate blood flow restriction with low-load resistance training effects. The blood flow restriction was performed by the experimental group, while the 22 participants in the control group did not receive blood flow restriction. After 16 weeks of intervention, the results revealed significant positive changes in the knee extensor muscles in the experimental group. The cross-sectional area of the muscle increased in the experimental group.

2.6 Blood Flow Restriction along with Whole Body Vibration

(Cai et al., 2021): In a randomized control trial, 20 non-professional adults participated in a study to compare the effects of whole-body vibration and whole-body vibration along with blood flow restriction. The outcome measures were muscle mass, endurance and one repetition maximal. The intervention blood flow restriction in combination

with whole body vibration improves strength and endurance significantly higher than the control group of whole-body vibration exercise only.

(Centner et al., 2020): The author performed a randomized control trial on 50 women to study the combined effect of blood flow restriction and whole-body vibration on strength and muscle bulk. The experimental group performed blood flow restriction with whole-body vibration, while the control group only performed whole-body vibration. The results showed increased positive results in the experimental group.

(Cai et al., 2018): A crossover randomized control trial was performed on eight males who were not physically active and performed 10 sets of blood flow restriction training combined with whole body vibration. The researchers found that the whole-body vibration along with blood flow restriction showed much better results on electromyography amplitude of thigh muscles.

(Centner et al., 2019): A randomized control trial was performed on 15 men experienced in resistance training. Participants were recruited randomly in three groups. These groups were the whole-body vibration group, blood flow restriction with the whole-body vibration and the control group. Results after the study revealed that blood flow restriction creates an enhanced whole-body vibration effect in its combination. It increases the neuromuscular and metabolic effects of the rehabilitation.

3. Research Gaps

There are a number of proven studies on the whole-body vibration effect on ACL-reconstructed adults. Still, there is a scarcity of studies on the blood flow restriction training and whole-body vibration effect in combination.

Although there are a few RCTs on the effect of whole-body vibration on ACL-reconstructed athletes and the effect of blood flow restriction on ACL reconstruction separately, there is no study on the effect of blood flow restriction training and whole-body vibration in ACL reconstruction athletes in both male and female athletes.

Studies are available on the whole-body vibration effect with conventional exercises in ACL reconstructed individuals, but there is so far no evidence of the effect of low-resistance blood flow restriction exercise and whole-body vibration and ACL rehabilitation protocol on ACL reconstructed sports athletes.

4. Problem Statement

There are a number of treatment protocols available for ACL reconstruction athletes. Still, muscle atrophy, impaired strength, balance and proprioception are creating challenges for the athlete to recover and return to sports. Research is still required for an effective, less time-consuming and a long run promising treatment protocol for athletes. There is a lack of Randomized Control Trials which prove the efficacy of blood flow restriction training and whole body vibration in athletes after ACL reconstruction. This combination can be an effective treatment option in the rehabilitation of ACL-reconstructed athletes to return to sports.

5. Objectives of Study

1. To measure changes in muscle girth, isokinetic strength and peak torque of quadriceps muscle after blood flow restriction training and whole body vibration in athletes after ACL reconstruction.
2. To measure the pain, Tegner Lysholm knee score and psychological status after blood flow restriction training and whole body vibration in athletes after ACL reconstruction.
3. To measure static and dynamic balance after blood flow restriction training and whole body vibration in athletes after ACL reconstruction.
4. To measure proprioception after blood flow restriction training and whole body vibration in athletes after ACL reconstruction.
5. To compare the differences between the outcome measures mentioned above in the blood flow restriction training and whole body vibration, in whole body vibration protocol only, and in blood flow restriction training only in athletes with ACL reconstruction rehabilitation.

5.1 Research Question

1. Is there any effect of blood flow restriction training and whole body vibration on muscle girth, strength and peak torque in athletes after ACL reconstruction?
2. Whether there is any effect of blood flow restriction training and whole body vibration on pain, Tegner Lysholm knee score and psychological status in athletes after ACL reconstruction?

3. Whether there is any effect of blood flow restriction training and whole body vibration on balance: static and dynamic in athletes after ACL reconstruction.
4. Is there any effect of blood flow restriction training and whole-body vibration on proprioception in athletes after ACL reconstruction?
5. Are blood flow restriction training and whole-body vibration more effective than whole-body vibration only in the outcome measures mentioned earlier in athletes after ACL reconstruction?

5.2 Hypothesis

1. Null Hypothesis: There will be no significant difference between all three groups in the mentioned parameters above.
2. Alternate Hypothesis: There will be significant differences between all three groups with the parameters mentioned above.

6. Research Methodology

6.1 Sample

Patients with ACL reconstruction will be assigned from The Central Reserve of Police Force (CRPF), Delhi, and randomly recruited to either of the three groups.

6.2 Sample Size

The sample size of the participants was calculated using G-power 3.1.9.4 using the change in data of strength in isometric contraction at 60 degrees of knee extensor muscle from a study done by (Ohta et al., 2003) in which the effect of blood flow restriction was assessed in ACL reconstructed patients. Thirty-two participants in each group (including 10% dropout) were represented as essential on the basis of 0.54 effect size, 0.05 alpha level and 0.805 power. Thus, the sample size for the study is 96.

6.3 Study Design

The study will be a Randomized Control Trial with three parallel groups (one experimental group and two control groups).

The subjects will randomly be allocated to either of the groups with an allocation ratio of 1:1:1. The randomization of the participants in the groups will be done by the Block Randomization method.

Ethical approval will be received from both the Manav Rachna International Institute of Research & Studies, Faridabad and the Central Reserve of Police Force (CRPF). Patients from the Central Reserve of Police Force (CRPF) will be randomly recruited to either of the three groups.

Registration for the study at the Clinical Trial Registry of India (CTRI) will also be done.

6.4 Inclusion Criteria

1. Age of participants between 20 and 40 years.
2. Athletes who have undergone ACL reconstruction with or without meniscectomy.
3. First arthroscopic reconstruction of ACL.
4. Played sports for at least 2 years before injury.
5. ACL injury and reconstruction in a single limb.
6. Isolated positive ACL integrity tests (clinical examination) along with imaging findings of ACL injury will be enrolled. According to clinical standards of practice, one should not rely only on imaging-based diagnosis as imaging findings are sometimes false.

6.5 Exclusion Criteria

1. Earlier history of any lower limb injury.
2. ACL injury in bilateral limbs.
3. Medical problems contradictory to whole body vibration and/or blood flow restriction: thrombosis, pregnancy, epilepsy, cardiovascular disease or any neurological condition.

6.6 Variables

A. Dependent Variables	B. Independent Variables
Pain	Whole Body Vibration
Isokinetic Strength	Blood Flow Restriction
Peak Torque	Blood Flow Restriction along with Whole Body Vibration
Muscle Girth	
Balance: Static	
Balance:Dynamic	
Joint Position Sense	
Tegner Lysholm Knee Score	
Psychological Questionnaire	

Figure 1: Dependent & Independent Variables

Source: Self

6.7 Procedure

Patients from CRPF, Delhi, will be randomly recruited to either of the three groups. Consent forms will be signed by the participants in Hindi and/or English language(s) after the procedures are explained to them and their rights are informed. The purpose of the study will also be presented to them. An investigator who is not part of any intervention will recruit the subjects. All the information on the subjects will be confidential.

6.8 Protocol

After assessing the eligibility of the participants for the study and including them according to the inclusion and exclusion criteria, their demographic data will be obtained. Thereafter, medical screening and a detailed physical and neuromuscular function assessment will be done. Baseline measurements will include pain, strength, muscle girth, ROM, balance (static and dynamic), peak torque, joint position sense, and postural control. The Experimental Group A will receive the low-resistance blood flow restriction exercises done on the whole-body vibration platform; Group B will receive whole-body vibration only. Group C will receive blood flow restriction only. The low-resistance blood flow restriction exercises, along with the whole-body vibration, will begin in the 6th week of the rehabilitation. The total period for the study will be 8 weeks (6th week to 14th week). At the baseline and after the 8th week of intervention, the outcome measures will be taken.

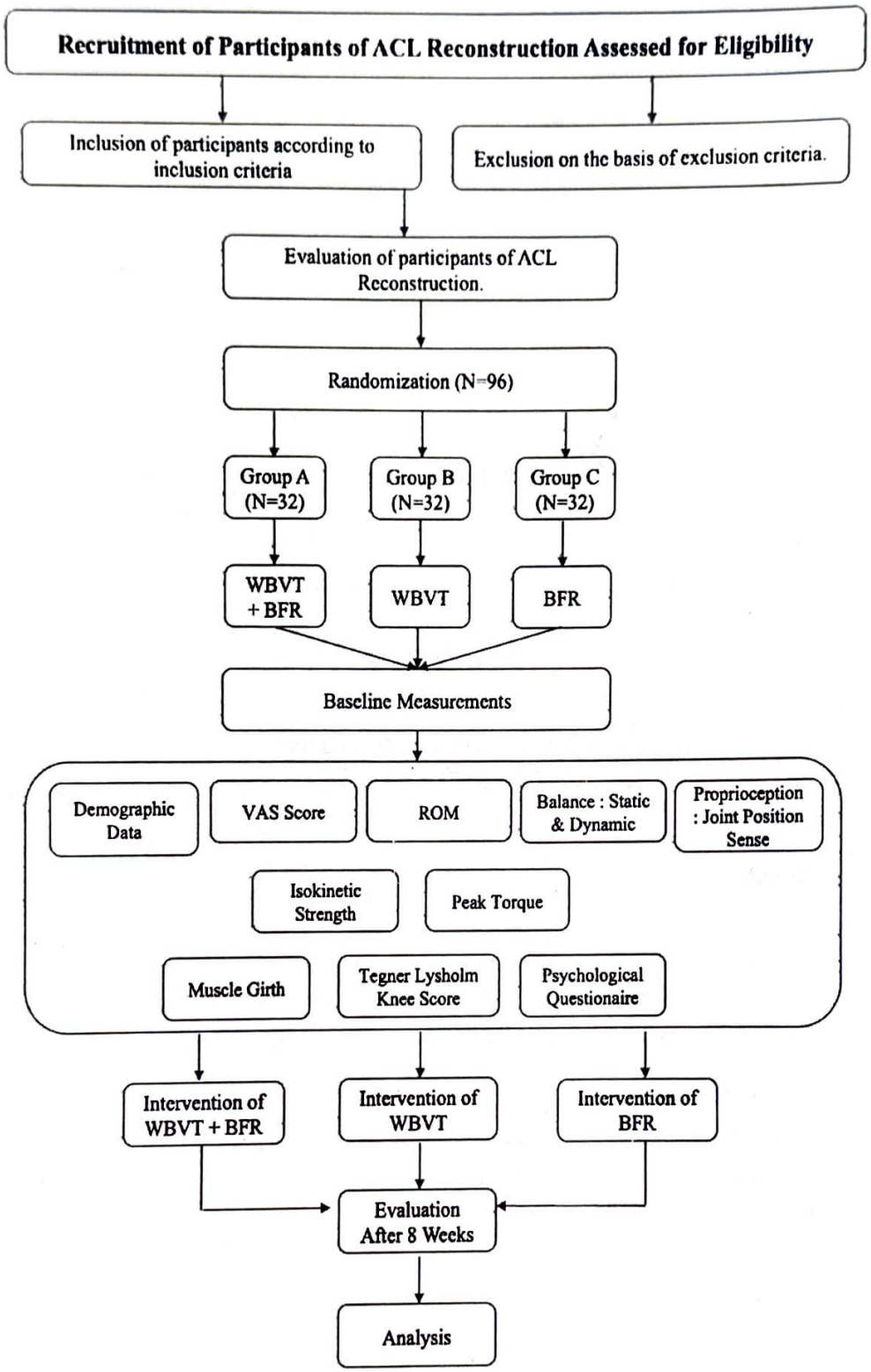

Figure 2: Flowchart of Methodology

Source Self

6.9 Interventions

Exercise Protocol

The exercise protocol for ACL reconstruction rehabilitation focuses on the goals of rehabilitation in the acute phase to the phase of return to sport. The time duration of the rehabilitation is about 4-5 months.

The acute phase includes exercises to reduce pain and swelling and to increase range of motion and quadriceps strength. The early phase focuses mainly on the terminal extension of the knee and weight bearing.

Full terminal extension and increased flexion range are important to proceed to the next phase. Eccentric exercises of the quadriceps and closed kinetic chain exercises begin in the 3rd week. Proprioception and coordination exercises start by week 5 to focus on balance.

Progression loading, skating, swimming, running, and dynamic exercises are essential to be focused on from week 10. Functional exercises and complex tasks begin in the 3rd month. (Mota da Silva, 2017).

Whole Body Vibration

The whole body vibration platform will have a frequency range of vibrations from 15 to 60 Hz, and the displacements vary from less than 1 mm to 10 mm. (Cardinale & Wakeling, 2005). The parameters for the treatment will be according to Zhang et al., 2021. The frequency and amplitude will gradually increase. Three sessions per week will be delivered. Isometric standing positions for 1 minute will be done. One minute period of rest will be given between each repetition. Other positions will be done according to Costantino et al., 2018.

Blood Flow Restriction: The blood flow restriction will be given for 8 weeks. The training will be low-resistance training for quadriceps and hamstrings. 30% 1 RM will be done with a controlled pressure of 150 mmHg in the thigh proximally. The time duration will be less than 30 minutes. The sessions will be done 3 times a week with 10 repetitions of static quads and 1/4th squats. 2 sets will be performed. (Marissa, 2018).

Blood Flow Restriction training on Whole Body Vibration: In this treatment, the participants will exercise in a standing position and squat on a whole-body vibration platform with an air tourniquet on the proximal thigh. The pressure on the tourniquet

will be 150mm Hg. The frequency on the whole-body vibration platform will be 20 Hz with 4 mm of amplitude. This frequency will increase gradually. A period of one minute rest will be provided in between each repetition.

6.10 Outcome Measures:

1) Neuromuscular control: To work on the quality of movement and joint control in all axial planes is neuromuscular control training. (Ageberg et al., 2010) Neuromuscular training includes sensorimotor function. These contain strength, balance and proprioception. (Ageberg & Roos, 2015)

2) Isokinetic Strength: Exercise at a constant velocity is isokinetic exercise. The participants sit on the dynamometer chair, and the pelvis and hip are stabilized. Various angles, such as 60, 180, 240 and 30 degrees per second, assess concentric knee flexion and extension. Data is then extracted from Biodex's computerized software. (Feiring et al., 1990). Biodex System 2 Isokinetic Dynamometer is a reliable method to attain quadriceps and hamstrings concentric strength. The isokinetic strength values are attained at 60 degrees and 180 degrees. Both of these angles give highly reproducible values.(Pincivero et al., 1997) The values will be attained at 60 degrees.

3) Peak Torque: The highest attained value during the total number of contractions of a muscle is known as the peak torque of the muscle. (Poletto et al., 2008). The peak torque is also assessed by the Biodex Dynamometer. The values will be recorded at 60 degrees of knee extension and then the data will be reduced from the Biodex software.

4) Balance: Static: A static balance assessment will be done using the BESS (Balance Error Scoring System). The test includes a double-leg stance with feet together, a single-leg stance on the non-dominant foot and a tandem stance with the non-dominant foot back. The test will be conducted with eyes open and closed, and the surface will be firm as well as foamy. There are six components which are evaluated. The duration is 20 seconds, and the feet are barefoot in each position. A score from 0 to 60 indicates balance. The scoring is done on the basis of:

    1. Hands movement off the hip.

2. Opening the eyes.
3. Stumbling or falling.
4. Forefoot of heel lift.
5. Improper test position for more than 5 seconds.
6. Beyond 300 flexion or abduction of the hip. (Jain et al., 2017)

Dynamic: The Star Excursion Balance Test (SEBT) assesses dynamic balance on an 8-line grid. The starting position of the foot is in the center of the grid. The participants are then asked to reach as far as they can on the lines in a clockwise manner. The foot will touch the ground with distal part and then again come back to the center for taking a double stance. The hands are on the iliac crests for the complete test. From the superior iliac crest to the medial malleolus of the tibia, the leg length is measured. The average of the three reaches is observed in every direction divided by the leg length. (Jain et al., 2017).

5) Proprioception: There are a number of techniques to assess proprioception. Joint position sense can be used to determine proprioception. It can be evaluated both in weight-bearing and non-weight-bearing limb positions. A universal goniometer will be used to assess the joint range. The goniometer will be tied to the proximal and distal end with a Velcro band. The test angle will be 30 degrees of knee flexion. The weight-bearing test will be done, such as the tested limb will bend to 30 degrees with the participant's eyes closed. The participant will use one finger to support the balance. The active limb with a goniometer will bend to 30 degrees, and then the position has to be on hold for 4 minutes while the other limb is off the ground. (Lokhande et al., 2013)

The non-weight-bearing test will be done while the participant will be sitting on the plinth with eyes closed and the legs will be out of the plinth. The examiner will passively flex the knee to 30 degrees. The participant has to hold the position for 4 minutes while identifying the position, and then he/she has to bring the limb back to the initial position. (Lokhande et al., 2013)

Three consecutive angles will be noted. The arithmetic difference between the test angle and the angle obtained will be the relative error. A mean of three relative errors will be calculated. (Lokhande et al., 2013).

6) Pain: The assessment of pain will be done using the VAS (Visual Analogue Scale). It is a valid and reliable tool to measure the intensity of pain. It has 11 points, where 0 is no pain, and 10 is the worst. (Breivik et al., 2008).

7) Psychological Assessment: KOOS (Knee injury and Osteoarthritis Outcome Score) is used to assess ADLs, pain, associated symptoms, sports function and knee-related quality of life. It is a valid instrument in the assessment of athletes with knee injuries. (Roos & Lohmander, 2003).

8) Muscle Girth: A measuring tape will measure the muscle girth in the thigh. It will be measured using a measuring tape in cm, according to the international metric scale. The measurements will be taken from the two sites. The sites will be 10 cm above the patella and 20 cm above the patella. (Marissa, 2018).

9) Tegner Lysholm Knee rating scale: This is a functional 100-point scale to rate the knee's functional parameters before going back to sports after ACL injuries and rehabilitation. It consists of 8 items with 25 points each for measuring pain and instability. It also includes an activity-grading system to analyze the pre-injury level, the present level and the level required to go back to sports. The higher the score and the activity level, the better the functional ability to return to sports. (Lysholm & Tegner, 2007)

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EFFECT OF BLOOD FLOW RESTRICTION TRAINING AND WHOLE BODY VIBRATION ON MUSCULAR, FUNCTIONAL AND PSYCHOLOGICAL PERFORMANCE IN ATHLETES FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

SHORT SYNOPSIS

by

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Abstract

Background/Introduction: Anterior Cruciate Ligament Reconstruction is the optimal decision for an athlete to return to sports after an ACL tear. It is a surgical intervention in which the torn ACL ligament is grafted to improve the knee's functions. Neuromuscular deficits are common after ACL injury. Functional recovery of the knee is incomplete in an athlete with ACL reconstruction if the rehabilitation does not include neuromuscular training.

Aims: This study aims to examine the effect of Blood flow restriction training and whole-body vibration on muscular, functional, and psychological performance in athletes following ACL reconstruction. It will also distinguish this result from the whole-body vibration-only protocol and blood flow restriction training individually.

Methodology: This study will be a Randomized Control Trial. There will be two control groups and one experimental group. Subjects will be selected using inclusion/exclusion criteria. These subjects will then be randomly assigned to the three groups (n=96). Outcome measures will be Pain, Muscle performance (Muscle girth, Isometric Strength, Peak Torque and Angular Velocity), functional performance (Balance-Static and Dynamic, Proprioception, Tegner Lysholm Knee Score and One-leg Hop test) and KOOS. The experimental group will perform blood flow restriction exercises on the whole body vibration platform. One control group will perform whole-body vibration only, and the other will perform blood flow restriction only.

***Keywords**: Anterior Cruciate Ligament (ACL) reconstruction, blood flow restriction (BFR), neuromuscular function, proprioception, whole body vibration (WBV*

Grammarly Report

Shivangi Sharma 20PhD003 grammarly

by Irshad Ahmad

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Report: Shivangi Sharma 20PhD003 grammarly

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rare words

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Measures average word length

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Measures average sentence length

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words per sentence

Writing Issues

150	**Clarity**	
82	Passive voice misuse	
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5	Intricate text	
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2	Ungrammatical sentence	
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Unique Words

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unique words

APPENDIX A: SCREENING FORM

Personal Information

1. Name

_____

2. Age/Gender

_____

_____

3. Height

_____

4. Weight

_____

5. BMI (kg/m2)

_____

6. Address

_____

7. Contact Number

_____

Medical History

Duration of injury:

How did you end up with the injury?

How did you get diagnose with the ACL injury?

Do you have any neurological deficit or sensation impairment in your lower limbs?

Do you have any other musculoskeletal problem in your lower limbs?

Are you pregnant?

Do you have any cardiovascular disorder like thrombosis?

Do you have epilepsy?

Have you been diagnosed with the vestibular disorder?

Do you have complaints/problems with vision?

Any other complaints?

Examination

Blood pressure

Examination of the reconstructed knee

Visual examination

Musculoskeletal examination

APPENDIX B: DATA COLLECTION FORM

Name:	Age/Gender:	Date:
Height (cm):	Weight(kg):	
Subject ID:	Group:	
Address:		Contact No:
Reconstruction Date:		
Type of reconstruction:		
Age:		

Measures	**Pre-intervention**	**Post-intervention**
Isokinetic Strength		
Peak Torque		
Balance: Static (BESS)		
Balance: Dynamic (SERB)		
Proprioception: Weight-bearing		
Proprioception: Non-weight-bearing		
KOOS		
Muscle girth		
Tegner Lysholm Knee Score		
ROM		
VAS Score		

APPENDIX C: CONSENT FORM

TITLE OF THE STUDY: "Effect of Blood Flow Restriction Training and Whole Body Vibration on Muscular, Functional and Psychological Performance in Athletes following Anterior Cruciate Ligament Reconstruction."

Invitation to participant

I have been informed by Ms. Shivangi Sharma, Ph.D. Scholar in physiotherapy (MRIIRS) (REG. NO. 20/PhD/003), that the above-mentioned study involves evaluation of isokinetic strength, peak torque, balance- static and dynamic, proprioception- weight-bearing and non-weight-bearing, KOOS, VAS score, ROM and muscle girth. Pre- and post-treatment with blood flow restriction and whole-body vibration therapy for comparing it with blood flow restriction training only and whole-body vibration individually. I have also been told that the study will assist in framing the improved evaluation and determining a superior protocol for the treatment of athletes after Anterior Cruciate Ligament Reconstruction.

I understand that I will be evaluated with pre-treatment reading and then will be given treatment three times a week for 8 weeks and again evaluated post-treatment, after 8 weeks. I also understand that this treatment does not have any side-effects which has any negative implications on my health.

I understand the medical information produced by this study will be maintained as per confidentiality regulations of the researcher.

1. I have been informed that the data if used for publication in the medical literature or teaching purposes; **names and other identifiers** **(example: photographs, audio/videotapes)**, will not be used without my written permission. I further understand that I may demand to see the photographs and videotapes and hear the audiotapes before giving this permission.
2. I understand that I may ask more questions about this study at any time and **SHIVANGI SHARMA** will be available to answer my participation or concerns regarding this study with a person not directly involved, I am aware that I can contact, **Dr. IRSHAD AHMAD**, Assistant Professor, Department of Physiotherapy, FAHS, Manav Rachna International Institute of Research and Studies, Faridabad., Haryana. I understand that my consent is voluntary and I reserve my right to withdraw it and discontinue my participation from the study at any time during the study.
3. I have explained to Mr. / Mrs. _____, the purpose of the research, the procedure required in the language he/she could understand to the best of my ability.

_____ _____

SHIVANGI SHARMA Date

4. I confirm that Ms. SHIVANGI SHARMA (Research Scholar) has explained to me in the language I can understand the purpose of the study and the procedure.

Therefore, I agree to give my assent for my participation as a subject in the study and I will be accountable for this decision.

_____ _____

Participant's Signature Date

Aadhar card number of Research Participant:

_____

APPENDIX D: HINDI CONSENT FORM

सहमति पत्र

अध्ययन का शीर्षक:

एंटीरियर क्रूसियट लिगामेंट पुनर्निर्माण के बाद एथलीटों में होल बॉडी वाइब्रेशन के साथ ब्लड फ्लो रेस्ट्रिक्शन चिकित्सा का प्रभाव।

प्रतिभागी को निमंत्रण:

मुझे सुश्री शिवांगी शर्मा, पीएच.डी. स्कॉलर इन फिजियोथेरेपी (एमआररआईआईआररएस) (पंजि. सं. 20/पीएचडी/003) द्वारा सूचित किया गया है कि उपर्युक्त अध्ययन में आइसोकाइनेटिक स्ट्रेंथ, पीक टॉर्क, बैलेंस - स्टैटिक और डायनामिक, प्रोप्रियोसेप्शन- वेट बियरिंग और नॉन-वेट-बियरिंग, केओओएस, वीएएस स्कोर, आरओएम और मसल गर्थ, सिर्फ रुधिर प्रवाह प्रतिबंध प्रशिक्षण (ब्लड फ्लो रेस्ट्रिक्शन) और व्यक्तिगत रूप से संपूर्ण शरीर वाइब्रेशन (होल बॉडी वाईब्रेशन) से तुलना करने के लिए रुधिर प्रवाह प्रतिबंध और संपूर्ण शरीर वाइब्रेशन चिकित्सा के साथ पूर्व और पश्चात उपचार का मूल्यांकन शामिल है। मुझे यह भी बताया गया है कि यह अध्ययन एंटिरियर क्रोसिए लिगामेंट पुनर्निर्माण के बाद एथलीटों के उपचार के लिए बेहतर मूल्यांकन और बेहतर प्रोटोकॉल का निर्धारण करने में सहायता करेगा।

मैं समझता/समझती हूं कि उपचार पूर्व रीडिंग के साथ मेरा मूल्यांकन किया जाएगा और तत्पश्चात 8 सप्ताह तक प्रतिसप्ताह तीन बार मेरा उपचार किया जाएगा एवं 8 सप्ताह के उपचार के बाद फिर से मूल्यांकन किया जाएगा। मैं यह भी समझता/समझती हूं कि इस उपचार का कोई ऐसा दुष्प्रभाव नहीं है जिसका मेरे स्वास्थ्य पर कोई नकारात्मक प्रभाव पड़े।

मैं समझता/समझती हूं कि इस अध्ययन द्वारा उत्पादित चिकित्सा जानकारी को शोधकर्ता के गोपनीयता नियमों के अनुसार बनाए रखा जाएगा।

1. मुझे सूचित किया गया है कि यदि चिकित्सा साहित्य या शिक्षण उद्देश्यों में प्रकाशन के लिए नाम और अन्य अभिज्ञापकों (उदाहरणार्थ फोटोग्राफ, ऑडियो/वीडियोटेप) के डाटा का उपयोग किया जाता है तो वे मेरी लिखित अनुमति के बिना उपयोग नहीं किए जाएंगे। मैं यह भी समझता/समझती

हूं कि यह अनुमति देने से पहले मैं फोटोग्राफ और वीडियोटेप देखने और ऑडियोटेप सुनने की मांग कर सकता हूं।

2. मैं समझता/समझती हूं कि मैं किसी भी समय इस अध्ययन के बारे में और अधिक प्रश्न पूछ सकता हूं और शिवांगी शर्मा इस अध्ययन के बारे में मेरी भागीदारी या किसी ऐसे व्यक्ति के संबंध में मेरी चिंताओं का उत्तर देने के लिए उपलब्ध रहेंगी जो सीधे तौर पर इसमें शामिल नहीं हैं, मुझे पता है कि मैं डॉ. इरशाद अहमद, सहायक प्रोफेसर, फिजियोथेरेपी विभाग, एफएएचएस, मानव रचना इंटरनेशनल इंस्टीट्यूट ऑफ रिसर्च एंड स्टडीज, फरीदाबाद, हरियाणा से संपर्क कर सकती हूं। मैं समझता/समझती हूं कि मेरी सहमति स्वैच्छिक है और मेरे पास इसे वापस लेने और अध्ययन के दौरान किसी भी समय अध्ययन से अपनी भागीदारी समाप्त करने का अधिकार सुरक्षित है।
3. मैंने श्री/श्रीमती _____ को शोध के उद्देश्य एवं आवश्यक प्रक्रिया को मेरी अधिकतम क्षमता में उस भाषा में समझा दिया है जिसे वे समझ सकते हैं।

शिवांगी शर्मा दिनांक

मैं इस बात की पुष्टि करता हूं कि सुश्री शिवांगी शर्मा (रिसर्च स्कॉलर) ने मुझे अध्ययन के उद्देश्य और प्रक्रिया को उस भाषा में समझाया है जिसे मैं समझ सकता/सकती हूं। इसलिए मै इस अध्ययन में एक पात्र के रूप में भागीदारी हेतु अपनी सहमति देने के लिए सहमत हूं और इस निर्णय के लिए जवाबदेह रहूंगा/रहूंगी।

प्रतिभागी के हस्ताक्षर दिनांक

शोध प्रतिभागी का आधार कार्ड नंबर: ----------

APPENDIX E: BESS EVALUATION FORM

Script for the BESS Testing Protocol Direction to the subject: I am now going to test your balance. Please take your shoes off, roll up your pant legs above ankle (if applicable), and remove any ankle taping (if applicable). This test will consist of 6 - twenty second tests with three different stances on two different surfaces. I will describe the stances as we go along.

DOUBLE LEG STANCE: Direction to the subject: The first stance is standing with your feet together like this [administrator demonstrates two-legged stance]. You will be standing with your hands on your hips with your eyes closed. You should try to maintain stability in that position for entire 20 seconds. I will be counting the number of times you move out of this position. For example: if you take your hands off your hips, open your eyes, take a step, lift your toes or your heels. If you do move out of the testing stance, simply open your eyes, regain your balance, get back into the testing position as quickly as possible, and close your eyes again. There will be a person positioned by you to help you get into the testing stance and to help if you lose your balance. Direction to the spotter: You are to assist the subject if they fall during the test and to help them get back into the position. Direction to the subject: Put your feet together, put your hands on your hips and when you close your eyes the testing time will begin [Start timer when subject closes their eyes]

SINGLE LEG STANCE: Direction to subject: If you were to kick a ball, which foot would you use? [This will be the dominant foot]. Now stand on your non-dominant foot. [Before continuing the test assess the position of the dominant leg as such: the dominant leg should be held in approximately 30 degrees of hip flexion and 45 degrees of knee flexion]. Again, you should try to maintain stability for 20 seconds with your eyes closed. I will be counting the number of times you move out of this position. Place your hands on your hips. When you close your eyes the testing time will begin. [Start timer when subject closes their eyes]

Direction to the spotter: You are to assist the subject if they fall during the test and to help them get back into the position. TANDEM STANCE: Directions to the subject: Now stand heel-to-toe with your non-dominant foot in back. Your weight should be evenly distributed across both feet. Again, you should try to maintain stability for 20 seconds with your eyes closed. I will be counting the number of times you move out of this position. Place your hands on your hips. When you close your eyes the testing time will begin. [Start timer when subject closes their eyes] Direction to the spotter: You are to assist the subject if they fall during the test and to help them get back into the position.

*** Repeat each set of instructions for the foam pad

Score Card

Balance Error Scoring System – Types of Errors

1. Hands lifted off iliac crest
2. Opening eyes
3. Step, stumble, or fall
4. Moving hip into > 30 degrees abduction 5. Lifting forefoot or heel
6. Remaining out of test position >5 sec

Which foot was tested: Left Right (i.e. which is the non-dominant foot)

Appendix F: Knee Injury and Osteoarthritis Outcome Score (KOOS)

Pain

P1 How often is your knee painful?	Never ☐	Monthly ☐	Weekly ☐	Daily ☐	Always ☐

What degree of pain have you experienced the last week when ?

P2 Twisting/pivoting on your knee	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
P3 Straightening knee fully	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
P4 Bending knee fully	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
P5 Walking on flat surface	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
P6 Going up or down stairs	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
P7 At night while in bed	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
P8 Sitting or lying	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
P9 Standing upright	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐

Symptoms

Sy1 How severe is your knee	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
stiffness after first wakening in the morning?	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐

Sy2 How severe is your knee stiffness after sitting, lying, or resting later in the day?	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
Sy3 Do you have swelling in your knee?	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
Sy4 Do you feel grinding, hear clicking or any other type of noise when your knee moves?	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
Sy5 Does your knee catch or hang up when moving?	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
Sy6 Can you straighten your knee fully?	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
Sy7 Can you bend your knee fully?	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐

Activities of daily living

What difficulty have you experienced the last week ?

A1 Descending	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
A2 Ascending stairs	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
A3 Rising from sitting	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
A4 Standing	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐

A5 Bending to floor/picking up an object	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
A6 Walking on flat surface	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
A7 Getting in/out of car	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
A8 Going shopping	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
A9 Putting on socks/stockings	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
A10 Rising from bed	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
A11 Taking off socks/stockings	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
A12 Lying in bed (turning over, maintaining knee position)	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
A13 Getting in/out of bath	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
A14 Sitting	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
A15 Getting on/off toilet	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐

A16 Heavy domestic duties (shovelling, scrubbing floors, etc)	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
A17 Light domestic duties (cooking, dusting, etc)	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐

Sport and recreation function

What difficulty have you experienced the last week ?

Sp1 Squatting	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
Sp2 Running	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
Sp3 Jumping	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
Sp4 Turning/twisting on your injured knee	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐
Sp5 Kneeling	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐

Knee-related quality of life

Q1 How often are you aware of your knee problems?	Never ☐	Monthly ☐	Weekly ☐	Daily ☐	Always ☐
Q2 Have you modified your lifestyle to avoid potentially damaging activities to your knee?	Not at all ☐	Mildly ☐	Moderately ☐	Severely ☐	Totally ☐

Q3 How troubled are you with lack of confidence in your knee?	Not at all ☐	Mildly ☐	Moderately ☐	Severely ☐	Totally ☐
Q4 In general, how much difficulty do you have with your knee?	None ☐	Mild ☐	Moderate ☐	Severe ☐	Extreme ☐

APPENDIX G: TEGNER LYSHOLM KNEE SCORE

This questionnaire is designed to give your Physical Therapist information as to how your knee problems have affected your ability to manage in everyday life Please answer every section and mark only the ONE box which best applies to you at this moment.

Patient Name: _____

Date: _____

1-LIMP

I have no limp when I walk. (5)
I have a slight or periodical limp when I walk. (3)
I have a severe and constant limp when I walk. (0)

2 - USING CANE OR CRUTCHES

I do not use a cane or crutches. (5)
I use a cane or crutches with some weight-bearing. (2)
Putting weight on my hurt leg is impossible. (0)

3 - LOCKING SENSATION IN THE KNEE

I have no locking and no catching sensation in my knee. (15)
I have catching sensation but no locking sensation in my knee. (10)
My knee locks occasionally. (6)
My knee locks frequently. (2)
My knee feels locked at this moment. (0)

4 - GIVING WAY SENSATION FROM THE KNEE

My knee gives way. (25)
My knee rarely gives way, only during athletics or vigorous activity. (20)
My knee frequently gives way during athletics or other vigorous activities. In turn I am unable to participate in these activities. (15)
My knee frequently gives way during daily activities. (10)
My knee often gives way during daily activities. (5)
My knee gives way every step I take. (0)

5-PAIN

I have no pain in my knee. (25)
I have intermittent or slight pain in my knee during vigorous activities. (20)
I have marked pain in my knee during vigorous activities. (15)
I have marked pain in my knee during or after walking more than 1 mile. (10)
I have marked pain in my knee during or after walking less than 1 mile. (5)
I have constant pain in my knee. (0)

6 - SWELLING

I have swelling in my knee. (10)
I have swelling in my knee only after vigorous activities. (6)
I have swelling in my knee after ordinary activities. (2)
I have swelling constantly in my knee. (0)

7 – CLIMBING STAIRS
I have no problems climbing stairs. (10)
I have slight problems climbing stairs. (6)
I can climb stairs only one at a time. (2)
Climbing stairs is impossible for me. (0)

8 – SQUATTING
I have no problems squatting. (5)
I have slight problems squatting. (4)
I cannot squat beyond a 90° bend in my knee. (1)
Squatting is impossible because of my knee. (0)

TOTAL: _____/100

Instructions: Please place a mark on the line to indicate the amount of pain you have had in your knee(s) in the past 24 hours.

RIGHT KNEE
No pain at all_____Worst pain possible

LEFT KNEE
No pain at all_____Worst pain possible

APPENDIX H: INTERVENTIONS

1. Exercise Protocol

The exercise protocol for the ACL reconstruction rehabilitation focuses on the goals of rehabilitation in the acute phase to the phase of return to sport. The time duration of the rehabilitation till the return to sport phase arrives is about 4-5 months.

Acute phase includes exercises to reduce pain and swelling and to increase range of motion and quadriceps strength.

The early phase focuses on mainly the terminal extension of knee and weight bearing. Patellar mobilizations are also important to prevent contractures in the first 8 weeks after reconstruction.

Full terminal extension and increased flexion range are important to proceed to the next phase.

Eccentric exercises of quadriceps and closed kinetic chain exercises begin from the 3rd week. Squats, leg press, proprioception and coordination exercises start by the week 5 to focus on balance.

Progression loading, skating, swimming, running, and dynamic exercises are essential to be focused on from week 10.

Functional exercises and complex tasks begin from the 3rd month and exercises to promote maximum strength, endurance, proprioception and sports- specific exercises with cutting and turning maneuvers are included from the 4th-5th month of the rehabilitation. (Mota da Silva, 2017)

2. Whole Body Vibration

Whole body vibration platform will have a frequency range of vibrations from 15 to 60 Hz and the displacements vary from less 1 mm to 10 mm. (Cardinale & Wakeling, 2005) The participants will stand bare foot on the platform.

The parameters for the treatment will be 20 Hz frequency.(Zhang et al., 2021) the frequency will gradually increase to 26 Hz with 4 mm of amplitude. 3 sessions per week will be delivered. Isometric standing position with one leg support and two leg support for 1 minute will be done. One set will have 6 repetitions and one minute period of rest will be given between each repetition. 1/4th squatting position with 25 degrees of knee

flexion with both the legs and with one leg will be done.(Costantino et al., 2018)

3. **Blood Flow Restriction**

   The blood flow restriction will be given for 8 weeks.

   The training will be low-resistance training for quadriceps and hamstrings. 30% 1 RM will be done with controlled pressure of 150mmhg in the thigh proximally. The time duration will be less than 30 minutes. The sessions will be done for 3 times in a week with 10 repetitions of static quads and $1/4^{th}$ squats. 2 sets will be performed. (Marissa, 2018)

4. **Blood Flow Restriction training on Whole Body Vibration**

   In this treatment, the participants will stand on both legs, stand on one leg and will do $1/4^{th}$ squat at 25 degrees of knee flexion on whole body vibration platform with an air tourniquet on the proximal thigh. The pressure on the tourniquet will be 150mm Hg.

   The frequency on the whole-body vibration platform will be 20 Hz with 4 mm of amplitude. This frequency will increase gradually to 26 Hz. The participant will stand on the whole-body vibration platform for each repetition for one minute for all the three exercises. A period of one minute rest will be provided in between each repetition.